

# EN200

## LAB #12

### SEAKEEPING LAB

#### Instructions

1. This lab is **conducted in the hydrolab** on the lab deck of Rickover Hall.
2. You will need to **bring this lab to the lab period**.
3. The lab consists of 2 separate parts - each aiming to reinforce a different aspect of understanding of seakeeping. The order in which you perform the 2 parts is unimportant and will depend upon your section number.
  - **Mass/spring System.** A vertically aligned mass/spring system will be analyzed.
  - **Roll Model.** The natural period of roll of a ship will be determined and its roll and heave dynamics observed in different frequency wave systems.
4. The lab is to be performed and submitted individually. You can ask questions and discuss the content of the lab, but the **submitted work must be your own**.
5. **All work must be shown on your lab for proper credit.** This means that you must show generalized equations, substitution of numbers, units and final answers. Engineering is communication. Other people should be able to understand your work.
6. **This lab is to be submitted at the end of the lab period.**
7. There should be sufficient work to last the entire 1 hour and 50 minutes of this lab. If you do finish early then check your work. If you get less than 100% you have done yourself an injustice by finishing early.

#### Student Information:

Name: \_\_\_\_\_

Section: \_\_\_\_\_

Date: \_\_\_\_\_

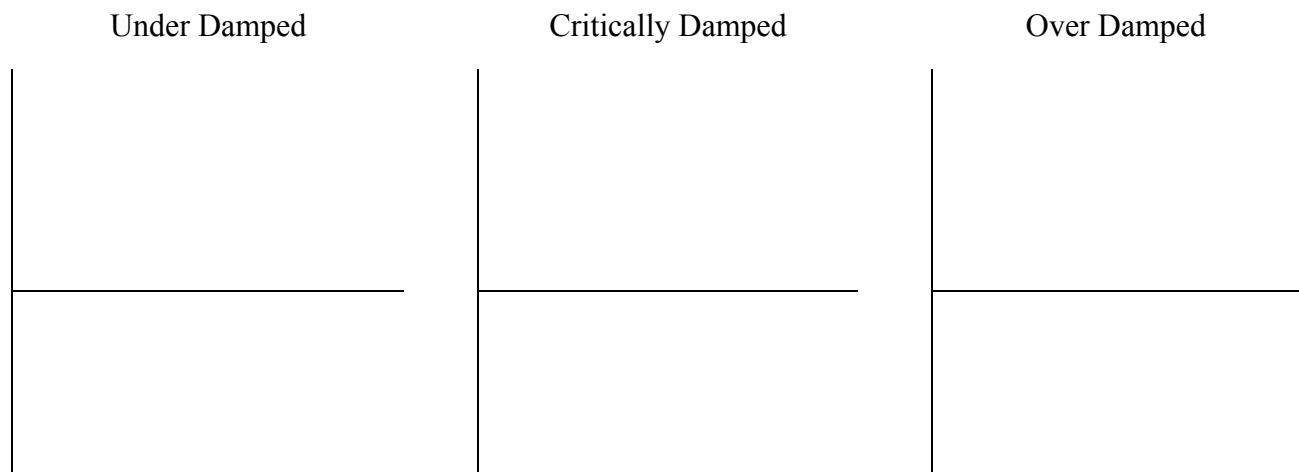
**Aim:**

- Reinforce the students' understanding of Simple Harmonic Motion.
- Familiarize the student with techniques that can predict natural periods of ship motions.
- Reinforce the students' understanding of ship motion when excited by forcing functions of different frequencies.

**Part 1: General Questions**

1. In your own words define "simple harmonic motion." \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
2. Which of the six ship motions can exhibit simple harmonic motion?  
a. \_\_\_\_\_ b. \_\_\_\_\_ c. \_\_\_\_\_
3. What is unique about the motions that can exhibit simple harmonic motions versus the ones that can't for a free floating ship? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
4. In your own words define what "natural frequency" of a system means as related to simple harmonic motion. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. In your own words define what a “forcing function” or “excitation force” is as related to simple harmonic motion. \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
6. What happens when the frequency of the forcing function is the same as the frequency of the natural frequency of the system? \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
7. In your own words define “damping” as related to simple harmonic motion? \_\_\_\_\_
- \_\_\_\_\_
8. On the axis below sketch motion displacement against time showing the difference between under damped, critically damped, and over damped systems.



## Part 2: Mass/Spring System

### Apparatus

9. The apparatus for this part of the lab consists of a mass/spring system vertically aligned. Figure 1 shows this system. The vertical scale allows the motion displacement of the mass to be recorded.

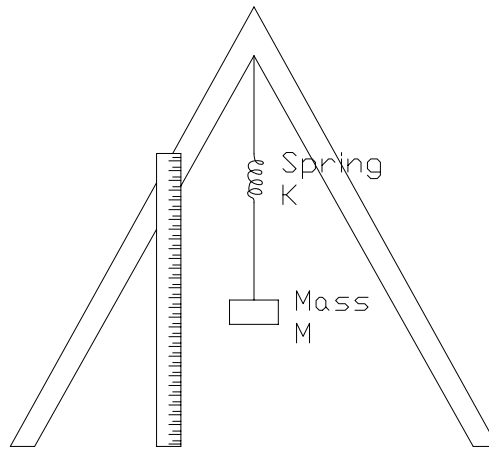


Figure 1 – Mass/Spring System

### Theory

10. The equation that describes the natural period of heave without damping of a simple mass-spring system is:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

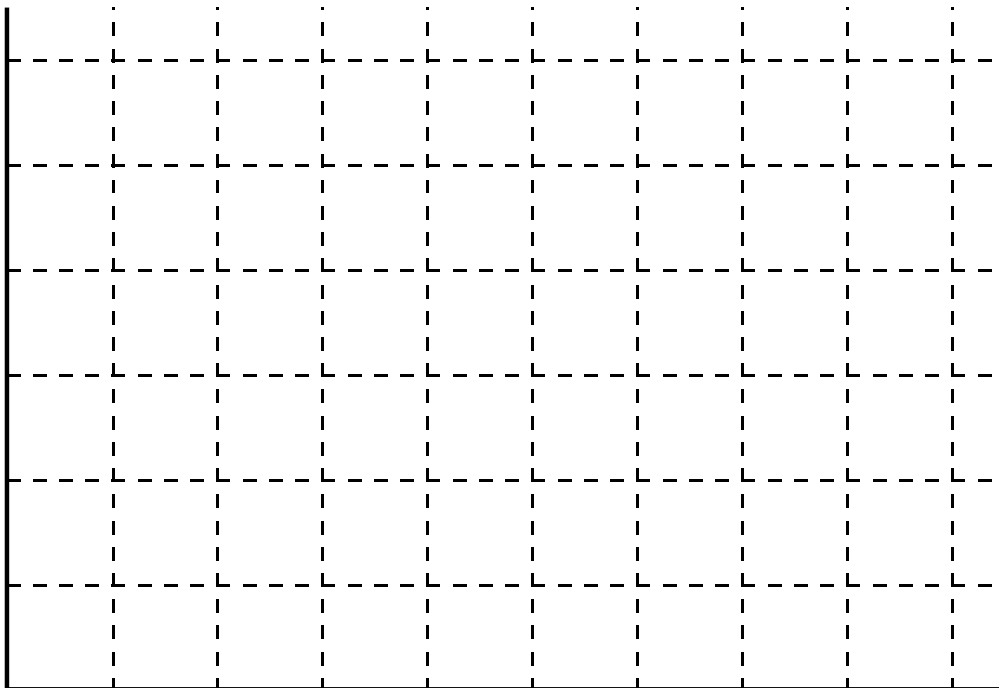
Where:  $k$  is the spring force constant in lb/ft.  
 $m$  is the mass of the system in lb-s<sup>2</sup>/ft.  
 $T$  is the period in s.

## Procedure

11. The first stage in this part of the lab is to calculate the spring constant of the spring. This is required to enable the use of the equation for the natural period to be used.
12. Place different weights on the system and record the corresponding deflection in the table below.

Weight (lb)	Deflection (inches)

13. Plot this data on the grid below. **Ensure you label the axes correctly.**



14. In the box below determine the slope of your plot and use it to calculate the spring constant, K.

**Hint:** If you are unsure of this step, compare the units of the spring constant, K with the units of the slope of your plot.

15. Select a total weight to use on the mass/spring system and calculate its mass M in  $\text{lb-s}^2/\text{ft}$ .

Weight selected in lbs \_\_\_\_\_

Corresponding Mass \_\_\_\_\_ ( $g = 32.17 \text{ ft/s}^2$ )

16. Use this data and the equation on page 4 to predict the period of oscillation for the mass/spring system in the box below.

17. Is this period reasonable? \_\_\_\_\_

18. The predicted period of oscillation will now be compared with that found experimentally.
19. Use the table below to find the period of oscillation of the mass/spring system. For each trial, record the time for at least 5 oscillations.

<b>Trial</b>	<b>Time for 5 Oscillations (s)</b>	<b>Period (s)</b>
<b>#1</b>		
<b>#2</b>		
<b>#3</b>		
<b>Average Period =</b>		

20. In the box below calculate the percentage difference between the calculated period of oscillation and that found experimentally.

21. Give 2 reasons why this percentage difference has occurred.

Reason 1 \_\_\_\_\_

\_\_\_\_\_

Reason 2 \_\_\_\_\_

\_\_\_\_\_

### Follow up Questions

22. The mass/spring system that has been analyzed can be used to model one of the ship motions. Which motion is this?

\_\_\_\_\_

23. When modeled in this way, what ship parameter is equivalent to the mass,  $M$ ?

\_\_\_\_\_

24. What ship parameter is equivalent to the spring constant,  $K$ ? **Hint:** Consider units.

\_\_\_\_\_

25. The major difference between the mass/spring system and the ship motion is the level of damping.

What damps the motion of the mass/spring system? \_\_\_\_\_

\_\_\_\_\_

What damps the ship motion? \_\_\_\_\_

\_\_\_\_\_

26. Which system is subjected to the greater level of damping? \_\_\_\_\_

\_\_\_\_\_

Why? \_\_\_\_\_

27. What addition could be made to the mass/spring system to more accurately model the motion of a ship? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



### Part 3: Roll and Heave Model

#### Apparatus

28. This part of the lab is performed in the 120' towing tank. A ship model is tethered across the tank to prevent it from yawing or swaying down the tank. The model has been instrumented to measure the amplitude of pitch and heave motions. Figure 2 shows a representation of the set up.

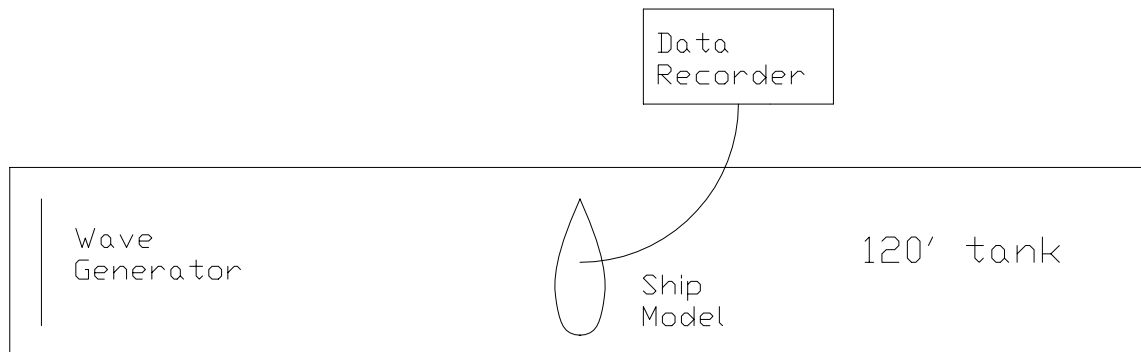


Figure 2 – The Roll Model Apparatus

#### Theory

29. The equation that describes the natural period of roll of a ship is as follows.

$$T_{roll} = \frac{C B}{\sqrt{GM_T}}$$

Where: C is the roll constant in  $\text{s/ft}^{0.5}$ .  
B is the beam of the ship at the operating water line in ft.  
 $GM_T$  is the metacentric height in ft.

The value of the roll constant C is usually found experimentally. If not known, a value of  $0.44 \text{ s/ft}^{0.5}$  is used.

## Procedure

30. The first step in this part of the lab is to determine the roll period of the model and use this to find its metacentric height. This is often referred to as a “Sallying Experiment”.
31. Use the table below to find the roll period of the system. For each trial, record the time for at least 3 oscillations. **Wait for the water disturbance to subside between each trial.**

Trial	Time for 3 Roll Oscillations (s)	Roll Period (s)
#1		
#2		
#3		
Average Roll Period =		

32. In the box below, use the equation on page 9 and the average roll period found above to calculate the metacentric height of the model.

33. Is the calculated metacentric height reasonable? \_\_\_\_\_

34. In the box below use the value for the average roll period to calculate the natural frequency of the roll motion ( $T_{\text{roll}}$ ). Calculate this frequency in both rad/sec and Hz.

35. The roll motion of the model will now be recorded when subjected to different frequency wave systems. 5 wave systems will be created to simulate various encounter frequencies. One encounter frequency will be at your computed value of  $\omega_{roll}$ , and the other frequencies will be above and below the natural frequency of roll.
36. Which frequency wave system do you predict will cause the greatest roll motion amplitude?  
\_\_\_\_\_
- Why? \_\_\_\_\_
37. Using your answer from (34) determine the wave frequencies that should be set on the wave generator controller. Place your answers in the appropriate cells of the results table (39).
38. The experimental procedure is as follows:
- When ready to perform each experiment, turn on the data recorder and start the wave generator.
  - Allow the model to roll for about 10 - 20 seconds then turn off the data recorder and the wave generator.
  - Restrict the model from rolling and wait for the wave system in the tank to subside to zero before commencing the next experiment.
  - Analyze the output from the data recorder and complete the table of results.



Note that the amplitude of the roll motion is linearly related to the peak to peak distance of the sine wave generated from the data recorder. Since the magnitudes of the roll motion are being compared, this is all that is required to record roll motion amplitude. In reality, the amplitude of the sine wave could be calibrated to indicate the exact extent of the roll motion.

39. Results table.

Experiment	Wave Frequency	Roll Amplitude	Heave Amplitude
	Hz	Degrees	Inches
#1			
#2			
#3			
#4			
#5			

40. Do these results agree with your predictions in (36)? \_\_\_\_\_

41. On the grid below, plot the roll and heave amplitudes against wave frequency. Use the left axis for roll amplitude and the right axis for heave amplitude, and put a curve through the data points to create roll and heave frequency response curves for roll of the model. **Ensure you label the axes correctly.**

42. What would have to be done to create a more accurate frequency response curve?

